Ph.D. SYNOPSIS

Source (Provenance) and Process (weathering, mineral sorting and grain-size) Control on the Geochemistry of the River Sediments: The Godavari River, India

ABSTRACT

Rivers are one of the important geological agents for erosion, transportation and deposition. The physical characteristic of turbulent river flows vary rapidly, irregularly and by order of magnitude in space and time. In the present study we focus on the Godavari River sediments in order to understand the provenance and hydraulic sorting controls on the mineralogy and geochemistry of the sediments.

The Godavari River is also known as Dakshin Ganga and it is second largest river basin after Ganga basin, with 12% of basin drainage of India. The origin point of Godavari is at Triambakeshwar near Nasik (Maharashtra) and travels 1,465 km through states of Maharashtra, Telangana and Andhra Pradesh, and finally meets the Bay of Bengal in the east at Antarvedi. It is one of the main sources of sediment to Bay of Bengal from India after Ganga and accounts 15% of India's annual sediment budget.

Formation of sediment in drainage basin depends on the supply of sediments from the source and river dynamics. The rock types traversed by Godavari River include Deccan basalt, Precambrian granite and sedimentary rocks from west to east. The chemical and mineralogical composition of sediments is strongly controlled by grain size, source rock composition, weathering and physical as well as chemical processes that modify the sediment while being transported.

The objective of study is to determine grains size variation in floods sediment and to investigate mineralogical and chemical composition of sediments which offers us to know hydrodynamic process during transport and deposition. It also allows us to constrain how and to what extent sediment composition is modified physically and chemically during transfer from detrital sources to deposition and how the natural process control concentration of detrital mineral and consequently chemical elements in the river sediments. The novelty of our approach includes systematic investigation of mineralogical and chemical data which will enable us to unravel the full record of provenance and hydrodynamic processes stored in sedimentary archives. Finally the findings of Godavari River will be compared with the other rivers from India and elsewhere in order to evaluate the source and process control on the mineralogy and geochemistry of the river sediments.

Keywords: Sediment; Grain-size; Mineralogy; Geochemistry; Godavari River; Deccan trap.

INTRODUCTION

Source compositions, silicate weathering, sedimentary sorting and physico-chemical conditions at the sites of weathering, transportation, and deposition are fundamental controls on the geochemistry of sediments (Nesbitt and Young, 1982; Nesbitt and Young, 1984; Johnson, 1993; Taylor and McLennan, 1995; Roser, 2000; Garzanti et al., 2009; Bloemsma et al., 2012; Garzanti and Resentini, 2016). However, assessment of relative influence of source *versus* process on the geochemistry of sediments deposited in different tectonic environments is not yet fully understood. In general, the source composition plays a dominant role on the sediment geochemistry in active continental margin settings (Nesbitt, 1979; McLennan et al., 1990; Garzanti et al., 2004; Goodbred et al., 2014); in contrast, the contributions of weathering and sedimentary differentiation processes are significant in the geochemical variation of passive continental margin sediments (McLennan, 1989; Garzanti et al., 2014). Similarly, relative control of clastic and non-clastic materials responsible for chemical variability in the sediments depends on the depositional environments. The trace element budget of sediments deposited near continental margins is controlled by clastic material mixed with organic matter (Plank and Langmuir, 1998; Carpentier et al., 2009). Whereas, trace element contents in sediments deposited slowly, away from the continental margins are influenced by sea-water, hydrothermal solutions and organic matter in addition to the detrital material (Plank and Langmuir, 1998; Plank et al., 2007; Chauvel et al., 2009).

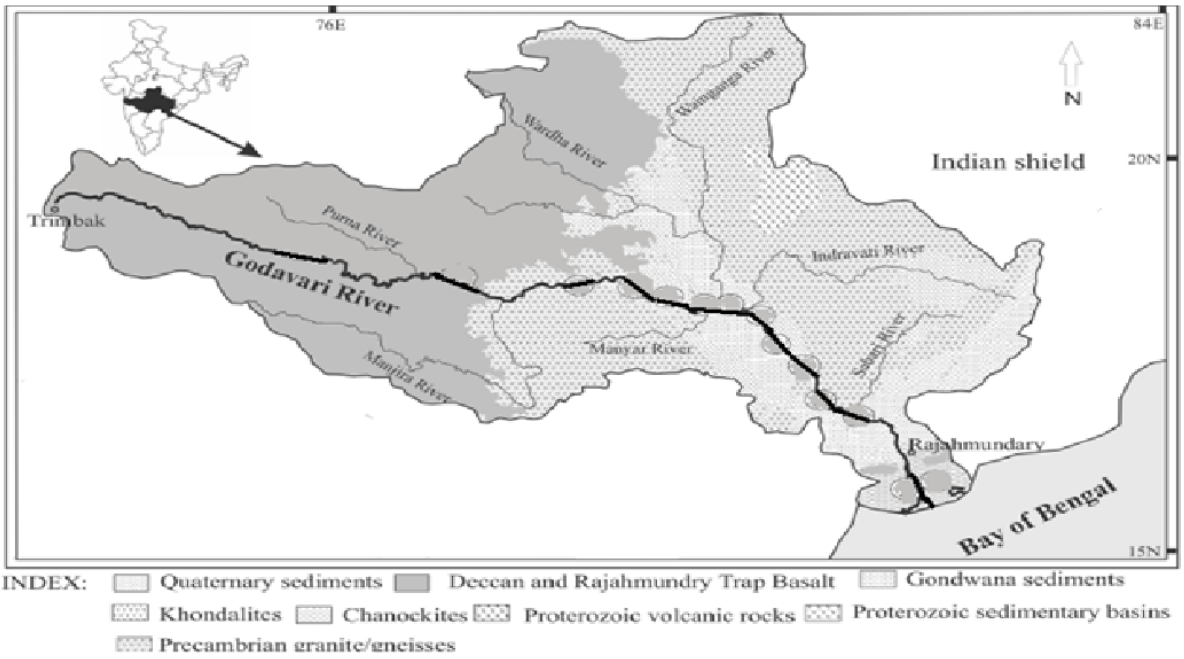
Trace element ratios such as Ni/Co, Th/Sc, Cr/Th, Sc/Nb, Rb/V and Eu/Eu*, considered to be independent from weathering and hydraulic sorting effects, are extensively utilized to characterize sedimentary provenances and mixing between different sources (Taylor and McLennan, 1985; Bhatia and Crook, 1986; Cullers, 1994, 1995, 2000; von Eynatten et al., 2016; Tang et al., 2016). Mineral sorting during transportation is the main complicating factor in quantitative estimation of contributions from different sources. Small proportions of accessory phases in sediments have dramatic effects on the trace element geochemistry and may lead to erroneous interpretations in the identification of sources and tectonic environments (Garzanti et al., 2010, 2011; Lupker et al., 2012; Garcon et al., 2013, 2014; Riboulleau et al., 2014).

Rivers are one of the important geological agents for erosion, transportation and deposition. A huge amount of continental weathering material is carried by the rivers to ocean. The major tropical rivers in Southern Indian peninsula include Godavari, Krishna and Cauvery. In the present study, an attempt has been made to understand the grain-size and

provenance control on the mineralogy and geochemistry of the Godavari River sediments. The flood- sediments along the banks and suspended sediments within the Godavari River are the focus of the present study.

The Godavari River, also known as Dakshin Ganga, is second largest river basin after the Ganga basin, with 12% of basin-drainage of India. The origin point of Godavari River is at Triambakeshwar near to Nasik (Maharashtra) and travels 1,465 km through the states of Maharashtra, Telangana and Andhra Pradesh, and finally meets the Bay of Bengal in the East at Antarvedi. The total drainage basin area in Maharashtra state is 49.42%. Godavari River has basin area of 313. 147 sq. km extending between the $16^{0}.0^{1}$N to $18^{0}.0^{1}$N latitude and $73^{0}.0^{1}$E to $83^{o}.30^{1}$ E longitude. Godavari River has four main tributaries namely the Pranahita, Manjra, Indravarti and Saberi. The Godavari River transports more than 50% of total sediment load of all tropical rivers in Southern Indian Peninsula. It is one of the main sources of sediments to Bay of Bengal from India after the Ganges system, and accounts 15 % of India's annual sediment budget. On the global scale Godavari river holds 9^{th} rank in sediment transportation. Unlike Godavari, the Krishna and Cauvery are mechanically less active and contribute less sediment to Bay of Bengal. The sediment load carried by Ganga and Brahmaputra are very higher than remaining rivers, because they drain the high erodible soil from Himalaya region.

Godavari basin contributes relatively large sediment load because of high degree of erosion of basaltic rocks. Nearly half of the basin area is occupied by the Deccan traps and remaining is occupied by Precambrian rocks. Erosion rates are higher in the central Indian region whereas they are lower in the south Indian region. Most of central India is underlined by the Deccan traps, whereas the southern region is underlined by the hard rocks, thus suggesting that the local geology plays a major control on the sediment yield of a river. As there is a systematic variation in the bed-rock lithology, it is believed that the Godavari River sediments would record this lithologic variation through mineralogy and geochemistry. This is the motivation for selecting the Godavari River for the doctoral work.



LITERATURE REVIEW

The Geochemistry of river sediments has been widely used for the determination of provenance, tectonics and weathering in the source region. The major and trace elements which are immobile such as Al, Fe, Ti, Th, Sc, Co, Zr and the rare earth elements (REEs), are useful indicators of the source (Taylor and McLennan, 1985; Singh and Rajamani, 2001; Tripathi and Rajamani, 2003). Geochemistry of river sediments is also robust tool for understanding of cycling of elements, erosional characteristics of river sediments (Martin and Meybeck, 1979; Milliman and Meade, 1983). The Chemical Index of Alteration (CIA) is sensitive indicator of the degree of chemical weathering of source and the contribution from different source rocks to the sediments can be examined by the A–CN–K plot (Nesbitt and Young 1982, 1984). Grain sizes have strong control on the chemical and mineralogical compositions of sediments and sedimentary rocks (e.g. Blatt et al., 1972; Basu, 1976). Factors including source rock lithology, weathering condition, and physical as well as chemical processes will modify the sediment while transportation (e.g. Johnsson, 1993).

The Amazon basin is the world's largest fluvial basin. The major and trace element geochemistry of Miocene and Pliocene deposits from the Ecuadorian, Bolivian and Peruvian Amazonian foreland basin indicate Neogene deposits are well homogenized, have an overall PAAS-like composition and they are mainly derived from a granodioritic crust. Physical

sorting seems to have played a minor role in the chemical composition of these sediments (Roddaz et al. 2005).

The geochemical variations of Ganga river sediments show that the combination of processes including erosion, weathering and sorting has together played a major role in progressively changing the chemistry from source rock to catchments bed-load to Plains bedload, active flood-plains and the older inter-fluve sediments in the Ganga River system (Singh 2009). Singh 2009 suggested that out of the major Himalayan lithologies, gneisses and Cambro-Ordovician granites of HHCS are the dominant source to the sediments.

The major, trace and rare earth elements geochemistry and clay mineral compositions in the river bed sediments of upper Godavari sediments indicate that they are mostly derived from weathering of basaltic rocks of Deccan volcanic province (Shilpa Vuba et al. 2015) whereas, the lower Godavari river sediments are derived from felsic rocks of peninsular India and sedimentary sorting is also evident. (Shilpa Vuba et al. 2013).

OBJECTIVE

The objective of the present study is to evaluate the controls of provenance and grain-size on Godavari River sediment mineralogy and geochemistry. A comparison with Himalayan and other Indian Peninsular Rivers will help us to verify crustal evolution patterns in different tectonic domains of India.

METHODOLOGY

Detailed field studies including sampling of all the flood- and suspended-sediments from the Godavari River, comprehensive grain-size analysis and mineralogy, and geochemical analyses for major, trace and rare earth elements for a large number of samples will be the methodology we adopt to achieve the objectives of the study.

Field survey and sample collection

Detailed field surveys will be conducted along the Godavari River and a large number of *in situ* samples will be collected from the flood-plains. Sediments will also be

collected from the suspended material within the Godavari River. All the required physical parameters will be recorded at the sites themselves. Field photographs will be taken to record the important field features.

Analyses of samples

Processing of the sediments based on grain-size will be carried out and petrographic studies will be made to understand minerals and their proportions. Geochemical analysis of representative bulk-rock sediments and grain-size separates will be carried out in the Geochemical Laboratories of National Geophysical Research Institute (NGRI), Hyderabad.

SIGNIFICANCE OF STUDY

River sediments represent the average composition of the exposed continental crust. The Godavari River traverses Deccan basalt, Archean/Proterozoic granitoids and Phanerozoic sediments from the site of its origin at Triambakeshwar to final destination at Antarvedi. Sediments collected in a vertical profile of the selected site will provide clues to the temporal variation in the sediment mineralogy and geochemistry, and also help us to recognize any paleo-flooding events. Sediments collected from different sites along the river course will provide clues to the changing lithology and help us to detect the provenance control on the sediment mineralogy and geochemistry. The final objective of the study will help us in evaluating relative controls of sources and processes on the sediment mineralogy and geochemistry.

PROPOSED WORK PLAN

First Year:

Literature Survey

A review of published literature on Godavari sediments and sediments from other Indian Peninsular and Himalayan Rivers will be carried out; unpublished material from Geological Survey of India (GSI) and other institutions specific to study area will also be collected.

Field work and sample collection

Detailed filed surveys will be conducted in selected sites along the banks of Godavari River for the collection of material from the exposed flood-sediments and suspended river sediments.

Second Year:

Petrographic and Geochemical analysis of rock samples

Petrographic studies will be carried out in the SES, SRTMU and geochemical analyses of representative rocks and constituent minerals will be carried out in the Geochemical Laboratories of National Geophysical Research Institute (NGRI), Hyderabad.

Third Year:

Interpretation of data

Field, petrographic and geochemical data will be synthesized and interpreted employing of the aforesaid tools.

1) Writing and submission of thesis -

The thesis will be written after the interpretation of data and achievement of objectives and will be submitted at the end of third year.

2) Presentation in Seminars.
3) Publication of research papers in National and International journals.

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